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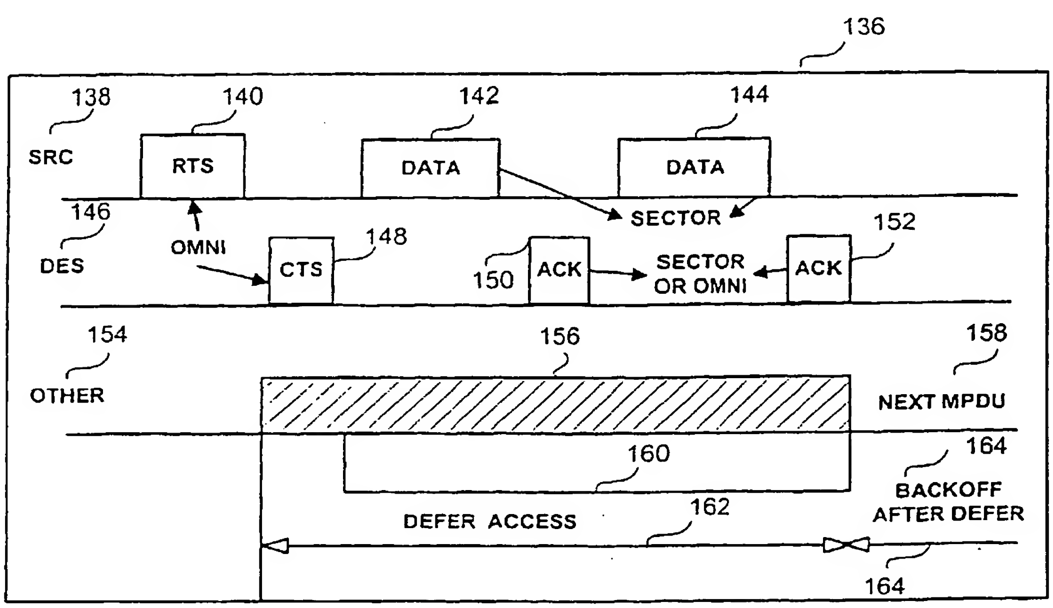
(54) **Title:** SYSTEM AND METHOD FOR INTRODUCING SECTORED TRANSCEIVING INTO WIRELESS NETWORKS



(57) **Abstract:** A system and method for the implementation of sectored transceiving into wireless communications protocols based on carrier sense multiple access (CSMA) protocol. The method includes the establishment of contention free periods during which sectored transceiving is enabled. Optimal communication sectors could be set up by the exchange of standard protocol messages enhanced to carry sector-related information or by the exchange of specifically developed and implemented sector-related messages among the particles of a wireless communication network.

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SYSTEM AND METHOD FOR INTRODUCING SECTORED TRANSCEIVING INTO WIRELESS NETWORKS

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention relates to a system and method for the introduction of sectored transceiving into wireless communications protocols having carrier sensing and/or collision handling based methods for their media access. In particular, the present invention relates to a system and method for the introduction of sectored transceiving into the IEEE 802.11 WLAN standards family based on Carrier Sense Multiple Access (CSMA) for media access.

DISCUSSION OF THE RELATED ART

The use of sectors in wireless communications networks is a known tool for network management providing substantial advantages, such as transmission power reduction, operational range increase, lower error rates, elimination of interference, better signal levels, channel reuse, network capacity increase, and the like. Sector usage is accomplished via the use of sectored transceivers and appropriate software support. Sectored antennas can be used in diverse wireless local area network (WLAN) devices such as access points, control points, wireless stations, and the like. A set of directional antennas is implemented in the transceiving devices; each antenna covering one portion of

the horizon (for example a sector out of six is 60 degrees wide). When communicating to a specific device, a controller device selects the sector of the sectored antenna that covers the sectored device, giving the benefit of directionality without sacrificing the coverage.

Referring now to Fig. 1A that illustrates a communications environment existing in the prior art in which the preferred embodiments of the present invention can operate. The environment contains a wired network 300, a wireless network 316, a wireless network 312, and a wireless network 302. Wired network 300 is coupled to wireless network 316 via standard communication lines 330, 328, 324, and via link 314. Specific activities of the wireless network 302 and the wireless network 312 can be controlled by the communication of information from wireless network 316. Therefore, the network 302 and the network 312 are communicatively linked to the wireless network 316 via a link 304 and a link 314' respectively. Although in the drawing only two wireless networks are shown it would be easily understood that in a realistically configured environment several wireless networks could be coupled to the network 316. Wired network 300 is a Local Area Computer Network (LAN) that includes various computing and communicating devices such as a network manager 306, a network printer 308, and a network terminal 310 linked by fixed communication lines such as one or more coaxial cables, twisted pair, fiber optics, and any other media to support wired communications. In another preferred embodiments a wireless communication network can replace the wired network 300. In yet other embodiments wired network 300 can be a Wide Area

Network (WAN). Although in the drawing only three wired network devices are shown it would be easily understood that in a realistically configured wired network a plurality of devices could operate. Network manager 306 includes a computing platform such as a Personal Computer (PC), a Sun workstation, a Macintosh computer, or a specialized network management device. The network manager 306 includes a memory for storing information and a process for accessing and processing the information. Wired network 300 is linked to Access Points (AP) 332, 326, 320 via respective communication lines 330, 328, 324. AP devices 332, 326, 322 include a computing and communication platform. The function of the Access Points is to bridge traffic from the wired network infrastructure 300 to the mobile terminals. Lines 330, 328, 324 include one or more coaxial cables twisted pair, fiber optics or any other media to support wired communication. Each AP includes a wireless transceiver (not shown) to support wireless communication. The network 300 is communicatively connected to a wireless access point (AP) 318 via a link 320. The AP 318 includes a wireless transceiver (not shown) to support wireless communication. The AP 332, 326, 322, 318 are communicatively linked to one or more mobile terminals (MT) 336, 338, 340, 342, 344 via links. Each MT includes a transceiver (not shown) supporting wireless communication. The AP 332, 326, 322, 318 are controlled by a network manager device 306 and communicate with the MT 336, 338, 340, 342, 344 through radio frequency signals transmitted by their respective transceivers.

In order to present a prior art communications system based on standards supporting sectored transceiving a simplified description of the

HiperLAN/2 standard will be given next. Note should be taken that sectored transceiving is also utilized in other known communications systems, such as cellular phone systems. However, the access methods of those systems are significantly different from the CSMA method. The description of the HL/2 system is intended to illustrate the implementation of sectored transceiving although the HL/2 system and the cellular phone systems are not relevant to the present invention.

The HiperLAN/2 (HL/2) standard is a WLAN technology that supports sectored or directional transceiving. The HL/2 standard utilizes the Time Division Multiple Access (TDMA) protocol, which is based on centralized frames. FIG. 1B shows a schematic illustration of the HL/2 centralized frames. The frames represent time periods and include an inner time division that is functional to sectored or directional operations. The HL/2 standard dictates that the communication is ordered in the environment. The Media Access Control (MAC) frames 12, 14, 16, and 18 are divided into ordered transmission portions. First, the entire set of the MAC frame broadcast maps BCH1 (20), BCH2 (22), and BCHn (24) one for each of the sectors are transmitted. Then the mapping of each sector FCH1 (26), FCH2 (28), and FCHn (30) is broadcasted through the relevant sectors. Subsequently the downlink portions DL1 (32), DL2 (34), and DLn (36) per sector are transmitted from the access point to the wireless terminal. The uplink portions UL1 (38), UL2 (40) and ULn (42) transmitted from the wireless terminal to the access point per sector follow. Finally the Random Channel Access portions RCH1 (44), RCH2 (46), and RCHn (48) per sector are

transmitted. While one sector is active the other sectors are passive. The wireless stations operate through a specific sector, perceive the sector's mapping at the beginning of the frame and can request or can be ordered to perform handoff/handover from one sector to another, according to specific criteria such as the reception quality of the various sectors implemented.

The group of the IEEE 802.11 WLAN standards is a set of interrelated technical documents describing a family of wireless transceiving technologies designed to operate in the 2.4 GHz and the 5 GHz frequency bands. The standards include the basic specifications of the technology and the associated dynamically added changes, modifications, and improvements. The standards support diverse physical layer specifications (PHYs) such as InfraRed (IR), Direct Spread Spectrum (DSS), Frequency Hopping Spread Spectrum (FHSS) in the 2.4 GHz band, and Orthogonal Frequency Division Multiplexing (OFDM) in the 5 GHz band. Currently 802-11 Task Group 'g' (TG)-related proposals exist for OFDM-based (or other) high-rate PHY for the 2.4 GHz band. The currently ratified 802.11 MAC is burst-based, employing a CSMA/CA mechanism to avoid collisions. This same 802.11 and/or 802.11 b MAC are applied to all PHYs. Currently there are also various other 802.11 related proposals and associated activities to add to the MAC specific features with some required PHY modifications, such as Quality of Service (Task Group 'e'), Dynamic Frequency Selection (DFS) and Transmission Power Control (TPC) for the European regulations (Task Group 'h'), and inter-AP protocol to enable MTs roaming across APs (Task Group 'f'). In the future there may be additional proposals for

improvements and added features. To the best knowledge of the applicant the ratified MAC is not designed to support sectors, and the CSMA/CA does not address the issue. In addition, to the best knowledge of the applicant sectors have not been considered under 802.11 and its sub-groups, sector-related device or chip have not been implemented or even designed, and no support for sectors exists in the MAC and in the RF front-end.

FIG. 2A shows the Carrier Sense Multiple Access (CSMA) and its Collision Avoidance (CA) derivative, which are known in the art. Note should be taken that the CSMA was initially intended and designed for wired systems. Thus, sectors were not considered as the concept of sectoring is completely unrelated to and utterly un-feasible in the wired networks. Therefore, to the best knowledge of the applicant, the 802.11 Task Group that extended the wired access method has never designed support for sectored transceiving. Each wireless station may contend for the wireless media whenever the channel is free after a specific time period has been lapsed. The time interval between the frames is called the IFS. The wireless station determines whether the medium is idle by utilizing the PHY carrier-sense function for the duration of the specified interval. Four different IFSs are defined to provide priority levels for access to the wireless media: short inter-frame space (SIFS), PCF inter-frame space (PIFS), DCF inter-frame space (DIFS), and extended inter-frame space (EIFS). FIG. 2B shows the 802.11 basic mechanism known in the art operative in reserving a channel for usage. It is a MAC CSMA function by which stations mark to themselves periods wherein the medium will be busy. The marking procedure is derived from

listening to the traffic and interpreting at the MAC level certain specific messages exchanged between the other stations. The occupation period information is stored in the stations in a Network Allocation Vector (NAV). Until the period is expired or otherwise reset according to specific access rules, the medium is considered busy and the stations are not allowed to perform attempts of occupation. Thus, the MAC level interpretation of the MAC messages originating from other stations obliges the entire set of stations to listen to all the other stations. This basic issue has prevented sectored transmission in the 802.11 technologies. The mechanism includes the Request To Send (RTS) 70 short message, publishing the reserved period to all the stations 74, 86 that can receive the source 68 transmitter, and the Clear To Send (CTS) 82 short message via which the destination receiver 74 publishes the remaining reserved time. As a result the stations 86 in the vicinity of the destination receiver 74 will be made aware that the media is occupied. All the stations 86 that receive the RTS 70 message and/or the CTS 82 message and/or other related messages suitably update the Network Allocation Vectors (NAV) 88, 90 thereof concerning the published period after the lapse of which the stations 86 are allowed to test the channel repeatedly for availability.

FIG. 3 shows the 802.11 standard optional Point Control AP, known in the art. The mechanism may be used to create a Contention Free Period (CFP). In the 802.11 standard a purpose of such optional CFP is to support certain time-bound applications.

FIG. 4A is a schematic illustration of the currently proposed Task Group 'e' (QoS) Transmission Opportunity Period (TXOP). The TXOP is created by the CF-Poll message 124 after a suitable Short Inter-Frame-Space (SIFS). The NAV 132 of all the receiving stations is updated in an appropriate manner in order to protect the contention-free TXOP period.

When considering the substantial advantages inherent in the use of sectors in wireless communications systems it would be readily perceived by one with ordinary skills in the art that there is a clear and present need for a novel system and methods that will provide the option of implementing the sectored transceiving feature into wireless networks, which are not yet supporting this extremely useful feature.

SUMMARY OF THE PRESENT INVENTION

One aspect of the present invention regards a wireless communications environment accommodating a set of wireless stations transceiving radio frequency signals, a carrier sense multiple access (CSMA) based wireless communications protocol, a method for implementing sectored transceiving of radio frequency signals, the method consists of establishing a contention free protected time period to be utilized for sectored transceiving, and setting up a directional sector for communication to be utilized for transceiving during the established protected time period.

A second aspect of the present invention regards a wireless communications environment accommodating a set of wireless stations having a set of directional antennas associated with sectors having the same directionality

transceiving radio frequency signals through the set of the directional antennas, a carrier sense multiple access based wireless communications protocol, a system for implementing sectored transceiving of radio frequency signals, the system includes the elements of a set of sectored wireless stations, a sectored access point device, a sectored control point device, a sectored traffic management component, and a sectored messaging component.

A third aspect of the present invention regards a wireless communications environment accommodating a set of wireless stations transceiving radio frequency signals, a carrier sense multiple access (CSMA) based wireless communications protocol, a method for implementing sectored transceiving of radio frequency signals, the method consists of establishing a set of sector-specific contention free protected time periods to be utilized for sectored transceiving, setting up a set of directional sectors associated with the sector-specific protected time periods for communication to be utilized for sectored transceiving during the established sector-specific protected time periods, collecting network stations-related sectored data, geo-location data, and distance data, scheduling of simultaneous sectored transceiving between subset of network stations based on the collection of the network stations-related sectored data, geo-location data, and distance data.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood and appreciated more fully from the following detailed description taken in conjunction with the drawings in which:

Fig. 1A is a schematic block diagram illustrating an exemplary communications system, known in the art, in which the proposed system and method can operate; and

Fig. 1B is a schematic illustration of a TDMA frame used in association with the HiperLAN/2 wireless protocol in a communication system operating in a sectored transceiving mode, as known in the art; and

Fig. 2A is a schematic illustration of the CSMA/CA wireless protocol operative in the 802.11 group of wireless standards, as known in the art; and;

Fig. 2B is a schematic illustration of the 802.11 technology basic mechanism, as known in the art; and

Figs. 3 shows the Point Control mechanism that can be used to create a Contention Free Period in the 802.11 technology, as known in the art; and

Fig. 4A shows the currently proposed TXOP mechanism for the creation of a Contention-Free-Period, as known in the art; and

Fig. 4B shows a proposed method of the sectored operation in association with the 802.11 technology, in accordance with a preferred embodiment of the present invention; and

Fig. 5 shows an another proposed method of the sectored operation in association with the 802.11 technology, in accordance with a preferred embodiment of the present invention; and

Fig. 6 is a simplified diagram illustrating yet another method for sectored transceiving in a CSMA based system, in accordance with a preferred embodiment of the present invention; and

Fig. 7 is a presentation of an exemplary message flow associated with sectored transceiving in a CSMA based system, in accordance with a preferred embodiment of the present invention; and

Fig. 8 is a simplified diagram illustrating the sectored transceiving between wireless stations in a CSMA based system, in accordance with a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

DEFINITION OF SPECIFIC TERMS USED

Network Allocation Vector (NAV): An indicator, maintained by each station, concerning the time periods over which the transmission onto the wireless medium (WM) will no be initiated by the station whether or not the station's clear channel assessment (CCA) function senses that the WM is busy.

Point Coordination Function (PCF): A class of possible coordination functions in which the coordination function logic is active in only one station in a basic service set (BBS) at any given time that the network is in operation.

Contention Free Burst (CFB): A technique for reducing MAC layer wireless medium (WM) access overhead and susceptibility to collisions, in which a single station may transfer. A transmission opportunity (TXOP) during which an enhanced station (ESTA) transfers a plurality of Mobile Protocol Data Units (MPDUs) during a single transmission opportunity (TXOP), retaining control of the WM by using inter0frame spaces sufficiently short that the entire burst appears to be a single instance of WM activity to contending stations. The use of CFB transfers may increase the aggregate data throughput within a given basic service area (BSA), but may also cause an increase of latency and/or latency variation (jitter) for all traffic being transferred within the same BSA.

Contention Free Period (CFP): A time period during the operation of the Basic Service Set (BSS) when a point coordination function (PCF) or hybrid coordination function (HCF) is used, and transmission opportunities (TXOP) are

assigned to stations by a point coordinator (PC) or hybrid coordinator (HC) allowing frame exchanges to occur without inter-station contention for the wireless medium (WM).

Contention Period (CP): A time during the operation of the basic service set (BSS) when a distributed coordination function (DCF) or hybrid coordination function (HCF) is used, and transmission opportunities are either generated locally as stations with pending transfers contend for the WM using a collision carrier sense multiple access algorithm with collision avoidance (CSMA/CA), or are assigned to stations by a hybrid coordinator (HC).

Controlled Contention (CC): A contention-based multiple access scheme that may be used by enhance stations (ESTA) at QoS level 2 or level 3 to request transmission opportunities (TXOP) from the enhanced point hybrid coordinator (HCEPC) without incurring the overhead of periodic polling nor the highly variable delays of DCF-based contention in a busy QBSS. Each instance of controlled centralized contention occurs solely among a subset of ESTAs that need to send reservation requests and which meet criteria defined by the HC. Controlled contention takes place during a controlled centralized contention interval (CCI) whose starting time and duration is selected determined by the HCEPC.

Hybrid Coordination Function (HCF): A coordination function that combines aspects of the enhanced distributed coordination function and the point coordination function to provide the selective handling of the MSDUs required for the optional QoS facility. The HCF is upward compatible from both DCF and

PCF and uses a uniform set of frame exchange sequences during both the CP and the CFP.

Hybrid Coordinator (HC): A type of point coordinator defined as part of the optional QoS facility, that implements the frame exchange sequences and MSDU handling rules defined by the hybrid coordination function. The HC operating during both the CP and the CFP. The HC performs bandwidth management including the allocation of TXOPs to ESTAs and the initiation of controlled contention intervals for the sending of reservation requests by the ESTAs. An HC is typically co-located with an EAP.

Transmission Opportunity (TXOP): An interval of time when a particular enhanced station (ESTA) has the right to initiate transmissions onto the wireless medium (WM). A TXOP is defined by a starting time and a maximum duration. During the contention period (CP), each TXOP begins either when the medium id determined to be available under the DCF rules or when the ESTA receives a QoS + CF-Poll from the HC. The duration of a [E]DFC TXOP is limited by a QBSS-wide TXOP limit distributed in beacon frames, while the duration of a polled TXOP is specified in the frame header that includes the QoS + CF-Poll function. During the contention free period (CFP), the starting time and maximum duration of each TXOP is specified by the HCF, using the QoS + CF-Poll function. Within the limits of each TXOP, decisions regarding what to transmit are made locally by the MAC entity at the ESTA.

Wireless Station (WSTA): An enhanced station (ESTA) that is neither located within an enhanced access point neither (EAP) nor a bridge portal.

The Request To Send (RTS) frame format: For all RTS frames the duration value is the time, in microseconds, required to transmit the pending data or management frame, plus one CTS frame, plus one ACK frame, plus three SIFS intervals. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer. The sending of RTS during the CFP is used to ensure that the addressed recipient ESTA is within range and awake, and to elicit a CTS response that will set the NAV at the stations in the vicinity of the addressed recipient. This is useful when there are nearby stations that are members of other BSSs and are out of range to receive beacons from this BSS. Sending an RTS during the CFP is only useful when the recipient is an ESTA, because a STA in the same BSS will have its NAV set to protect the CFP, hence unable to respond. Using the same duration calculation during the CFP as specified for the CP is directly applicable for all cases except when the RTS is sent by the EPCHC, and the following frame includes a +CF-Poll. However, even in this EPC HC case, the same RTS duration calculation can be used, because that duration results in a CTS duration, hence NAV setting the vicinity of the recipient, which lasts until after the beginning of the transmission in response to the +CF-Poll. It is reasonable to assume that stations, which are able to receive the CTS and set their NAVs are also able to defer to CCA (busy) resulting from the ESTA's transmission in response to the +CF-Poll. This avoids the complexity of having the responding ESTA determine in real time the transmit duration of a response to a +CF-Poll which has not yet been received.

A system and the methods for the introduction of sectored transceiving into communications protocols having carrier sensing and/or collision handling based methods for their media access is disclosed. The preferred embodiments relate to the IEEE 802.11 WLAN standards group. It is important to note that other embodiments of the present invention could relate to other CSMA based wireless protocols and the 802.11 standard is utilized only as an example in order to contribute to a ready understanding of the proposed system and method. The term “sectors” refers to the use of sectored or directional antennas and methods of traffic management, scheduling in time, in frequency, in geographical direction (X, Y, Z) domains, and power control in order to transmit and receive via wireless means. The proposed system and method of the present invention regard Access Points (APs), Control Points (CPs), and Mobile Terminals (MTs). A Control Point is a logical or physical function that may be used for the management of a wireless network. Typically, a CP would be co-located as a logical function within the AP, or could be installed in a separate device. For reading clarity, in the text of this document the terms AP and CP will be used interchangeably. The text of this document will refer interchangeably to the terms sector and directional as well. Transceiving is used to mean transmitting and/or receiving. The document uses the terms omni, omni-directional, and the like, as the opposite to sectors or directional, meaning transceiving to/from all directions. Furthermore, wireless terminal (WT) and mobile terminal (MT) are used interchangeably. The present invention is applicable to the family of carrier sense multiple access (CSMA) wireless protocols, which includes collision detection (CD), collision

avoidance (CA), and the like. As 802.11 is CSMA/CA-based, the document uses the terms CSMA/CA and CSMA interchangeably.

Presently sectors are not used in 802.11 WLANs or any other CSMA based systems known to the applicant because no support thereof exists in the current standard. The innovative concept of the proposed system and method will be made clear by considering the reason for this lack of support. The reason is related to the basic design of these networks. The 802.11 medium access rules are all based on PHY Carrier Sensing, i.e., the ability of the stations to sense the wireless medium and identify when the wireless medium is clear of traffic. Additionally, a complementary MAC carrier sensing mechanism is used, which utilizes listening to and interpreting of specific messages in order to set and reset the MAC NAV. Only at the PHY and MAC "empty" time and pending additional access sub-rules the CSMA stations are allowed to try and access the wireless medium. The implementation of sectors in 802.11 or other CSMA based systems has been considered until now impractical and/or extremely inefficient as sector usage contradicts the underlying mechanism of the channel access method employed in the CSMA systems. If sectored transmissions are allowed, i.e., transmissions that are actually designed not to be heard by all the network but just by directed stations, then the basic access rule of carrier sensing is contradicted. The innovative steps are: the introduction of a concept stating that it is feasible to introduce sectored transmission in CSMA based systems, in the provision of methods to accomplish sectored operations in said systems, and in the provision

of methods for the stations to determine and communicate their selection of which sectors to use in such directional communication.

Within CSMA based systems all the stations are provided with the capability of listening to the traffic network. Furthermore the stations are obliged to utilize this capability in order to listen for the traffic in order to avoid collisions. By definition the introduction of sectored transceiving breaks down the principle associated with the medium access rule. The objective of the sectored transceiving is to enable only stations associated with a specific sector to communicate in order to exploit the specific sector-related directionality for power reduction and/or increased range. As a result stations operating in the 802.11 or in any other CSMA based network are no longer assured to perceive correctly either the existence of traffic itself for its PHY carrier sensing, and/or access related messages for their MAC carrier sensing, from the environment and consequently may deduce incorrect conclusions regarding the availability of the wireless media and might interpret incorrectly the appropriateness of initiating interruptions.

The present invention introduces the concept of sectored transceiving into 802.11 WLANs by proposing a system and a method for the usage and management thereof. The proposed system and method can be implemented in connection with the existing 802.11 standard (PHY including 2.4 GHz and 5 GHz and MAC, 802.11b 1999 edition or earlier 802.11) as well as on the recently suggested 802.11 MAC enhancements, such as the current proposals under 802.11 TGe (QoS), TGh (DFS, TPC for Europe), and TGf (inter-AP

communication). These standard groups enhancements do not include sectors use. To the best knowledge of the applicant sectored transceiveing was not even discussed by the standard groups. It will be appreciated by one with ordinary skills in the art that the essential part of the invention is the underlying concept and the basic supporting methods described below rather than specific detailed implementations, which may change as a result of the immaturity of the 802.11 standard.

The main innovation includes the concept that once the 802.11 wireless media is made protected for certain time periods, then these periods can be used by sectored or directional transmissions. During the protected periods the network stations are not required to listen to the traffic in order to establish that the wireless media is busy and therefore to refrain from interruptions. The invention proposes a system and method that utilizes protected periods referred to as Contention Free Periods (CFP) which are created by the broadcast of omni-directional signals or messages, for the use of sectored transceiving. The system and method proposed by the present invention provide that during the suitably created protected time periods sectored unicast traffic or multicast traffic intended exclusively for stations on a specific sector can be exchanged between the stations. The system and method proposed provides that the protected time periods can be made contention free. The system and method of the present invention further suggests how to use specific Contention Free Periods (CFPs) that are created by the 802.11 standard groups such as the 802.11e in order to be utilized for different specific purposes. The invention also suggests a system and

method operative to the coordination of the sectors use by the transmitter and the receiver, as well as to provide roaming capability to the receiver between sectors of the same transmitter. Sectored transceiving can take place between APs and MTs or between MTs without the presence of AP (e.g. in an ad hoc network) according to the methods proposed by the invention.

The first preferred embodiment of the present invention describes a system and method for sectors transceiving based on the ratified 802.11 standards without the implementations of the not yet ratified mechanisms currently proposed by the Task Groups TGe, TGh, and the like. The embodiments of the present invention can operate within a communications environment as shown in Fig. 1A. Fig. 1A is illustrative only and it is not the only communications environment in which the various preferred embodiments of the present invention can operate In the preferred embodiments of the present invention, the WLAN 316 of Fig. 1 is an IEEE 802.11-type wireless network. IEEE 802.11 is a set of broadband radio transmission technologies based on the CSMA/CA protocol, which is known in the art. In other embodiments of the present invention alternative CSMA/CA-based technologies could be used, such as OpenAir, HomeRF, or the like. The features of the IEEE 802.11 standards are known. The 802.11 standards do not support currently sectored transceiving.

According to first embodiment of the present invention stations transmit the network-occupation-related information thereof in omni-directions. The information includes data belonging to the 802.11 Network Allocation

Vector (NAV), such as the occupation duration. For example, NAV related messages that are to continue to be broadcasted in omni-direction are Request To Send (RTS) messages, Clear To Send (CTS) messages, ACK messages that carry NAV information, Beacon messages, relevant Poll messages, and the like. These messages include all the time or part of the time NAV related information. To mark the time in which the wireless media is occupied by other stations NAV is used. During the marked time the stations are not allowed to interrupt the wireless media with transmissions but are obliged to wait for the media to become free at the end of the occupation before attempting to contend for the unoccupied media. However, for transceiving messages and traffic that do not include NAV related information, the stations may now utilize sectors. The NAV related information will be transmitted to all directions and will be received by the network's entire set of stations in order to protect the time portion required by the station occupying the wireless media for the sectored traffic exchange thereof. The traffic itself, if unicast (i.e., intended for a specific single station) or multicast (i.e., intended for a set of stations on the same sector) can now be transmitted in a specific sector in the direction of the intended receiving station. The sector (Sx1-1) at the transmitter (X1) that is the best serving the receiver (X2), and the receiver (X2) sector (Sx2-1) which is in the best transmission towards the transmitter (X1) can be determined by the two stations (or between a single station and a set of stations in multicast) utilizing various means. For example, X1 could omni-transmit the NAV related RTS thereof such that all the network stations will be made aware that X1 has just occupied the wireless media for a

certain period. Then the X1 could transmit other RTSs, or short empty messages, or a new protocol message, or any other type of transmission, through each one of the sectors thereof. The receiver X2 would listen through the circular sector transmission and identify the best-received transmission, or the "good enough" transmission through using measurements of signal strength, signal to noise ratio, error rate, or any other appropriate attribute. The receiver X2 then transmits back to X1 a CTS message, an ACK message, or any other short transmission through the entire set or a specific sub-set of it own implemented sectors. The transmission is further used to feedback to X1 the number of the X1 transmissions, which X2 determined to be the best for it (i.e., on which sector X2 received X1 in the best manner). Thus, X1 can use the received transmission to determine on which sector to transmit the data to X2 as well as which sector to use for reception from X2. Obviously X1 can still use omni-reception for receiving transmissions from X2. Omni-transmission can be physically done by using an omni-antenna in addition to the sectored antennas, or by switching the transmission to the entire set of the sector antennas if such an operation is feasible in the implementation. The transmitter and receiver could be either APs or MTs, so that the embodiment applies to ad hoc networks as well. In numerous wireless applications X1 is a sectored AP while X2 is an omni-directional AP. In this case X2 transmits via the omni-antenna thereof only a single message back to X1. It will be easily understood that even when X2 does have multiple sectors implemented response can be sent to X1 through one of the sectors (probably

through the sector through which X1 is received in the best manner) or in omni directions.

In another method to establish the direction of the sectors transceiving, geo-location information can be transmitted, or otherwise distributed such as by means of network management provisioning. Consequently stations in the network will be made aware of the location of the other stations and the direction of the sectors thereof. The geo-location information, such as GPS positioning data, can be attached suitably to current standard messages, such as a Beacon message, or to messages uniquely designed and developed as part of the proposed system and method. Consequent to a first station establishing the sector, through which the first station should transmit to a second station, the sector-related information can be retained by the first station and can be used again later. Thus no need exists for the first station to re-establish the sector-related information in every new data/control exchange. Periodic update requests can be employed to refresh the sector-related information.

In yet another method based on the ratified standard mechanisms, a Point Coordination Function (PCF) is employed to create the Contention Free Period (CFP). The PCF is an optional feature of the 802.11 standard. Typically, the PCF resides in an AP device. Therefore, this embodiment of the proposed system and method applies only to networks that contain an entity with the optional PCF implemented therein. The PCF is provided with the capability of creating contention free periods (CFP). The purpose of the PCF is to support certain time-bound implementations. The proposed system and method could

utilize the PCF for sectored transceiving. Within the CFP the same mechanisms as detailed above are used to provide sectored transceiving.

Fig. 4B illustrates an exemplary operation of the proposed system and method, in accordance with the first preferred embodiment of the present invention. The Contention Free Period (CFP) is established via the omni-directional broadcast of the standard RTS-CTS (140-148) messages between a source device (SRC) 138 and a destination device (DES) 146. In the first preferred embodiment of the invention both the SRC 138 and the DES 146 are transceiving stations within a WLAN. The data 142, 144 is unicast through a specific sector. In the case illustrated on the currently discussed drawing the sector is already known from a prior data/control message exchange between the stations SRC 138 and DES 146. The ACK feedback message 150 can be transmitted on a specific transmitter sector, if such a sector exists and if it is known to the DES 146 through which sector it needs to transmit such that the SRC 138 could receive it, The ACK 150 can be also transmitted in omni-direction as defined in the 802.11 standard, if the DES 146 does not have sectors or if the DES 146 does not have the information concerning the sector through which the DES 146 should reply to the SRC 138. The essential portion of the transmittable information is the data 142, 144. By using sectors the data 142, 144 will be typically transmitted efficiently with substantially low power consumption.

Referring now to FIG. 5 that shows the manner in which two wireless stations, such the SRC station 168 and the DES station 184 establish mutually the sectors through which they could communicate efficiently within a given

Contention Free Period (CFP). The exemplary procedure is performed by the transmission of a set of short messages. At the beginning of the CFP the SRC 168 transmits short messages through each of the three sectors implemented therein. Although only three messages are shown it would be easily understood that several short messages could be transmitted through several sectors implemented within the SRC 168. The DES 184 transmits a short reply message 188 in order to inform the source 168 concerning the sector through which the rest of the communication should take place. In the first preferred embodiment of the invention the reply message 188 is uniquely designed and introduced into the system in order to support sectored transceiving. The SRC 168 is aware of the number of messages that will be exchanged in the course of the process, as the number of messages is a function of the number of the sectors used by the SRC 168 increased by one to reflect the presence of the unique reply message from the DES 184. Thus, the SRC 168 is capable of inserting the exact length value of the period into the RTS 170 message in order to protect the complete period needed for the exchange of information. The three short sectored trial messages S1 (174), S2 (176), and S3 (178) are transmitted without guard intervals placed between them. In other embodiments a predefined guard time may be added. The sectored trial messages S1 (174), S2 (176), and S3 (178) are novel messages designed and implemented specifically for the sectored transceiving feature. To the novel short sectored message S1 (174), to the RTS message 170, and to any other message operative in the creation of the Contention Free Period, certain information elements may be attached. The attached information elements carry data

concerning the number of sectors to be tried for transmission by the SRC 168, the length of the guard time interval between each sector short trial message, the maximum transmission power allowed on each sector, and the like. When the information elements are not attached to a standard CFP-creating message, such as the RTS 170 for example, then the elements may be included in a newly developed and implemented message type specifically designed to support the sectored transceiving feature. The information is attached to all the S messages, such as to S1 (174), to S2 (176), and to S3 (178) as S1 (174) alone could not be used as the carrier of the information elements. The receiver 184 may not receive a specific S message transmitted through a specific sector but if all S messages carry the information then the DES 184 will receive one of them. The method of transmitting multiple times the same information is inefficient but necessary in the currently described embodiment as the DES 184 may not be aware of the number of sectors to be listened on before sending the reply 188. In order to achieve enhanced efficiency a new potential message B1 (172) could be implemented. Message B1 (172) could contain the sectors related information and to be broadcasted omni-directionally just before the transmission of the sectored trial messages S1 (174), S2 (176), and S3 (178). This flexible arrangement allows the SRC 168 to send trial transmissions only through self-selected sectors rather than through all the operational sectors implemented in the SRC 168. For example, if the SRC 168 had previously had sectored communication with the DES 184 and a certain amount of time elapsed, the SRC 168 may desire to revalidate the previously used sector or may want to enable the DES 184 to re-

select the sector. It will be substantially accurate and efficient to estimate that the selected sector will either be the previously selected one or a substantially close one to the previously selected one rather than all the existing sectors. The estimate can be based on the time elapsed, the distance of the DES 184 from the SRC 168 (where feasible), and on the mobility pattern as identified by the SRC 168 (where feasible). The DES 184 determines the sector through which the transmission of the SCR 168 was received in the best manner. Consequently the DES 184 response message, referred to as the reply 188, could notify the SRC 168 concerning this information. Alternatively or additionally, notification could be also sent concerning the reception levels for the entire set of the sectors, or a specific subset of sectors, derived from specific measurements made by the DES 184. As a result the SRC 168 is capable of deciding through which sector to transmit to the DES 184, of verifying the decision made by the DES 184, and of understanding better the relative geo-position of the DES 184. Such measurements involve the RSSI, the Signal-to-Noise ratio, and the like. In accordance with the feedback report concerning the performance of several measured sectors the SRC 168 is allowed to make the best possible estimate concerning the sector through which to transmit instead of having the DES 184 make the decision.

In yet another method for sectored transceiving in omni-directional and CSMA based wireless systems, such as the 802.11, a Contention Free Period or Controlled Contention Periods can be created for selected sector, using a priority-like method. During the created periods contention will be allowed for a

station operating on the selected sector alone, while the rest of the network stations will remain silent (i.e., the period will be protected from them). Note should be taken that in the currently operative CSMA based systems the contention periods are created for the entire set of network stations, as the concept of sectored operation is not introduced into said systems. Each station will listen for periodic sectorally transmitted beacons or any other similar sectorally transmitted message. The messages could include unique newly designed and developed messages or could include existing messages modified for the support of the sectored transceiving feature. The station could then recognize the most suitable sector to transceive through. The stations will store and hold the information. When the stations are moving across the network area, the stored sector identification will be updated, similarly to the manner known in the art where a search is done during the movement of a station is moving across the network space between the various APs. Between APs the station updates the frequency of the transmission, stays on the same frequency and listens for sectorally transmitted messages. When moving in such a manner the station may use timing information from contemporary sector sectored-beacon message concerning the timing of the other sectors sectored-beacon such that the station will have the information operative to determine when to expect the sectored-beacon messages of the other sectors, rather than wait and listen for them. The CP can now use sectored Contention Free Period (CFP), or Controlled Contention Periods (CCP). The CP transmits media allocations, such as with CF-Poll messages to create TXOPs (in the 802.11e), with the addition of identification

data of the sector to which the period is allocated. The allocations are transmitted by the CP/AP in omni-direction such that the entire set of stations can receive them, but as they contain the sector identification data, which is allocated or allowed to contend for the wireless medium, only those stations that selected to transceive through the specific sector will contend for the medium. The proposed method can be accomplished utilizing existing messages wherein the priority fields are replaced with a priority + sector combination information, or where sector identification field is added to the existing priority messages, or where priority messages are added, if such messages are not defined. For example, in 802.11e the proposed Controlled Contention message can be enhanced with a sector identification data field, such that only stations that decided to transceive through the sector (and comply with the existing Controlled Contention access rules) are allowed to contend for the medium. Consequent to the transceiving through the selected sector the stations can then lower their transmission power.

In another method suggested by the present invention the coordination of the two stations, each aware of the sectors through which to transceive, is achieved by the sectorally transmitted beacons (or similar transmissions) and by the allocation of Controlled Contention (CC) or Contention Free Period (CFP) per each sector. To enhance the synchronization a station may send a message such as a measurement response (or an information element added to existing messages) to the CP/AP/HCF to make it aware through which sector the station intends to transceive and/or the quality of reception experienced by the station through a subset of sectors (e.g. three sectors through with the reception is the best).

Consequently the CP/AP/HCF can plan ahead and allocate time according to the received information rather than trying to check continuously whether the stations want to use a specific sector. The Controlled Contention (CC) and Contention Free Period (CFP) method listed above may include any other form of establishing access, such as periodic access (where according to requested and/or granted parameters a periodic access is allocated to the stations; e.g. X time units every Y interval), and the like. For example, the CP/HCF/AP can allocate X time units of Controlled Contention (CC) period per the method above every X time units for each sector; and/or for each sector and certain priority of the applications/stations on it as it is proposed in 802.11e.

Referring now to FIG. 6 that illustrates the process. The MT1 (240) and the MT2 (246) receive the sectored beacon 244 (or similar) message transmitted by the CP/HCF/AP 236 on a specific sector and decide that they receive it well enough. Subsequently the MT1 (240) and the MT2 (246) determine to transceive through the specific sector. The MTs 240, 246 can either return a message to the AP/CP/HCF 236 informing it of their measurements of the sectored-beacons 244 (or of part of them, or only of their final decision), or they can wait until the CP/AP/HCF 236 allocates time for this sector on its own accord. Returning the message is not shown. Subsequently, the CP/AP/HCF 236 allocates Controlled Contention (CC) and/or Contention Free Period (CFP) for the sector by omni-directional transmission of priority-like RTS, CC or CFP messages with enhanced sector identification data. Then, the CP/AP/HCF 236 could send through the sector it wants to transceive through a message such as an

802.11 CF-end message. Such messages indicate that the declared media occupation period is now finished, many times earlier than expected. By sectored transmission of the message, only stations that are on the sector, or close to it, will receive the message and will now attempt to contend for the non-occupied media. In this manner contention will be limited and most of the network stations will still wait for the occupation period to end as declared initially. Subsequently, the MT1 (240) and the MT2 (246) can contend as long as they comply with the existing priority rules such as those of 802.11e. In case the new sector-priority like messages, or the information elements, are not added into the 802.11 standard, the CP/HCF/AP 236 will first occupy the media without allowing any station to contend (such as by omni-directional sending RTS/CTS to itself, and the like), and then send the sector allocation messages separately at the application level rather than at the standard level. Thus, the media will be busy for all the sectors and the traffic will be conducted in one sector only. Using another option, the CP/HCF/AP 236 could send the allocation messages on the relevant sector only. As a result only the stations that receive the broadcast will contend for the media. As the CP/AP/HCF 236 will not occupy the media but rather poll per sector (with or without priority per existing or per proposed standard mechanisms), then contending stations will include stations from other sectors that have a good enough reception of the broadcast and which do not implement the method proposed by the invention (if it is not part of the standard). Therefore the stations that do implement this invention will contend and if they are successful, they will use the sectored transceiving feature. If they are not

successful then they will contend again. When a station is successful in the limited sector-based contention, it will benefit from the useful features of the sectored transmission such as transmission with reduced power or extended range. The implementing station and the implementing CP/AP/HCF 236 could omni-directionally broadcast RTS/CTS or other standard mechanism to ensure that their contention is reckoned by the other stations.

FIG. 7 illustrates an example of the message flow. The flow includes several optional steps indicated with dashed lines. The CP/AP/HCF 252 transmits a sectored beacon message 254 to the station 1 (250). The message 254 could be transmitted periodically on all the sectors and includes useful information such as sector identification, and other sector-related and beacon-related parameters. The station 1 (250) optionally takes suitable measurements of the sectored, optionally selects a sector to transceive through, and optionally transmits a message 256 back to the CP/AP/HCF 252. The message 256 could include a set of measurement results and/or the selected sector identification. In order to create protected periods the CP/AP/HCF 252 Omni-broadcasts a CC/CFP creation message 258. The message 252 could be one of the various existing, TG-proposed or specifically designed and developed new messages such as the RTS/CTS message, the CF-Poll message, the TXOP message, and the like. Optionally the CP/AP/HCF 252 could transmit a protected period termination message 260. Optionally the CP/AP/HCF 252 could transmit a CC/CFP protected period creation message 262 for a specific sector. The optional message 252 may be one of the set of existing, TG-proposed, or newly developed messages such as

a sectored RTS/CTS, sectored TXOP, sectored CF-Poll, and the like. The station 1 (250) transmits to the CP/AP/HCF 252 the messages 264 for the purposes of omni-contention, omni-reply (CTS),omni-data, sectored-data and the like.

The second preferred embodiment of the present invention describes the system and the methods thereof for sectored transceiving based on the ratified 802.11 standards, on the potential implementation of the techniques currently proposed (but not yet ratified) in their original or slightly modified form (such as the TGe, TGh, and the like), and on mechanisms unique to the present invention that are not included in any standard enhancement proposals. The details of the standard enhancement proposals are not essential to the system and the method proposed by the invention. Rather, the concept and the idea of these enhancements are essential. If the standard bodies will not adopt the essential concept, a unique and/or proprietary mechanism may be devised to accommodate the system and the method for the implementation of the invention. According to the 802.11 TGe (QoS) a protected period of time, which is controllable by the AP, the CP, the ESTA, the HCF, or the like, is suggested, in addition to similarly functioning periods created in the basic 802.11 standard as were described hereinabove (e.g., RTS/CTS, and the CF-Poll). For example, the already ratified message CF-Poll is designed to allow a CP/HCF to control and allocate the wireless media for a specific non-contention period, within which each station may be addressed, be transmitted to, or be granted a transmission period. According to the current TGe proposals some of such periods are referred to as TXOP (Transmission Opportunity). An another mechanism currently proposed in

the TGe is referred to as Controlled Contention (CC), where the respective granted period thereof is referred to as the Controlled Contention Interval (CCI). Similarly to the other proposed enhancements to the standard, the CC is not designed for sector usage. The present invention proposes to utilize in an innovative manner the CC mechanism or similar priority based mechanism) as a tool for creating protected periods for the wireless media. In the current TGe proposal the CCI could be used as a periodic interval, releasing the stations from the need to re-ask for allocation and releasing the HC from the need to re-poll the stations. During the CCI all the stations with a certain minimum priority value, which is declared within the message, can contend for the wireless media. If the extension of the standard proposal is enacted then each station can be given a specific CCI. During the CCI the station can exchange sectored traffic as its period is protected from the other stations by specific means broadcasted in omni-directions. Once protected, transmissions may be directional as there is practically no probability of being interfered by other stations. The other stations do not need any longer to listen to the ongoing directional traffic in order to determine that the wireless media is busy.

The second preferred embodiment of the invention utilizes contention free periods (CFPs) to transmit in sectors. According to the teaching of the invention, once a CFP or a Controlled Contention Period (CCP), such as a TXOP or a CCI, has been set by using the CF-Poll, CC, or any other standard, currently proposed or proprietary message, then within the set period the stations are protected. Thus the protected stations can use sectored transceiving without being

interfered by other stations, which cannot receive the sector utilized. The concept is substantially equivalent to the concept disclosed in the first preferred embodiment. The second embodiment differs from the first embodiment by utilizing more advanced techniques to set the protected periods. To the best knowledge of the applicant these techniques were not proposed to the suitable standard groups for ratification and no indications exists that these techniques will become an integral part of the 802.11 standard in the foreseeable future.

Additional methods are being suggested by which the CFPs or the CCIs are set per sector. In one such method the allocating entity can first broadcast in omni-directions a protection message for a complete contention free period. Subsequently the entity divides the complete protected period into sectored transmission sub-periods. The division is based on information gathered from the network over time. The information is used to identify the best working station-sector combinations. For example, the entity can poll a new station, or periodically the previous ones, through the entire set of implemented sectors. According to the reply messages of the polled stations the allocating entity can determine the sector to serve the answering station with. The stations will listen throughout the complete contention period. Based on the accumulated information the allocating entity will determine to which stations to allocate time on each sector. Alternatively, a new enhancement to the standard can be added by which at the beginning of the complete free period the allocating entity will broadcast in omni-directions the precise time points associated with each sector period start. In this manner the stations will only need to wake up and listen to

their sector by being aware which sector they are being served with. The sector allocation of the complete CFP can be either sent in a separate and a newly designed and developed message, or in a new extension to an existing message typically used to create the complete CFP. Thus, messages including TXOP information, or the TXOP element, or the CC, can be extended to contain sector-relevant information, such as the relative starting time of the period, the sector identification, or the like. The transmitter and the receiver could be either an AP and/or a MT, as long as the QoS mechanisms, such as currently proposed under the standard TGe (HC/HCF), exist. Therefore the currently described embodiment applies also to ad hoc networks.

Even more advanced techniques that could be utilized for the exchange of sector-related information between the 802.11-based wireless stations will be dealt with next. The exact format of the messages is not relevant to the implementation of the system and methods proposed by the present invention. Rather, the concept, and the principal idea underlying the usage of such messages and some of the data fields thereof are essential. Messages to be used could include message formats currently being proposed by the TGf (inter-AP protocol) for specific non-sectored-operation-related purposes, or could include other new message formats. Many of the messages could be sent either as new messages, such as enhancements to the standard, or application level messages. The messages could be implemented also as new information elements attached to the standard messages of the protocol. Several messages as related to the proposed

system and method of the invention will be described next. These messages are also relevant to the previous embodiments.

Sectored Beacon message: A periodic Beacon message can be transmitted by the AP, CP, HCF, ESTA, WT, and the like, in each of the sectors separately. The Sectored Beacon could be a current 802.11 Beacon message, a new subset of it, an extension of it, or a completely new message. The purpose of the sectored transmission is to enable the receivers receive through the entire set of the implemented sectors in order to enable the receivers to select the best sector to be used in their temporary location. The Sectored Beacon message should include a sector number or a similar identification. The message could further include useful information pertaining to the sector, such as maximum allowed transmission power, next TXOP period for the sector, and the like. Optionally, relative or absolute timing data concerning the next or the prospective sectorally transmitted beacons transmittable to other sectors, geo-location information, such as the GPS positioning of the station, and the direction of the sectors could be included. Furthermore, geo-location information, such as the GPS positioning of the station and the direction of the sectors, could be added to the standard Beacon and/or to the new Sectored Beacon messages.

Sectored TXOP and/or CCI elements: As described in association with the first preferred embodiment of the present invention, such information can be either broadcasted in omni-directions, and/or broadcasted through the sectors. The information could contain sector-specific contention free period data. Such data could include sector identification, the point in time when the period

commences (relative and/or absolute time points), the point in time the period terminates (relative and/or absolute time points), the period's duration (relative and/or absolute time points), the maximum allowed transmission period, the maximum allowed transmission power, and the like.

Sectored CF-Poll message: This type of message could be broadcasted per sector and/or in omni-directions. The message could include the sector identification, the set of stations being polled, and/or the sector allocated time for the stations.

Sectored Sector-Reception element/message: This new message may be sent back by receivers to notify the transmitter about the sector they want to be served with and/or about measurement reports on the reception of one or more transmitted sectors. In the case of reporting back measurements, the transmitter (the source) can make the sector selection decision rather than the receiver (destination). The message may include information about one or more sectors received, such as the sector identification, the received power, the received power to noise ratio, and the like. The information elements could be attached to other existing and/or currently proposed messages. For example, the information element could be attached at the end of an existing ACK message that the receiver transmits at certain times. When the reception deteriorates below a certain threshold a station can decide to attach the sector's reception information elements to an ACK message along with a suitable request for a sector handoff.

Sectored DFS and TPC messages: Dynamic Frequency Selection and Transmission Power Control are currently being proposed under the TGh. Some

of the currently proposed messages can be made sectored or sector-associated. For example, an instruction issued by the allocating entity for the stations to measure a certain frequency can be modified such as to include sector identification. Similarly, measurement results being reported back to the allocating entity could contain sector identification and the measurement results for each such sector. Similarly, transmission power related elements and messages could be sectored by including the sector identification to which they refer.

Sectored MAC header: MAC headers may contain the sector identification through which they are transmitted. The receiving stations to assess the reception per sector in addition could use the information, or instead of the specific Sectored Beacon messages described hereinabove.

In the third embodiment of the present invention a method operative in the creation of sectored Contention Free Periods (CFP), and the usage of sectored traffic will be described. The first innovation is the sectored CFPs in wireless CSMA based protocols such as the 802.11. Thus, a source transmitter can create multiple traffic channels, between the source transmitter and other stations or for the use of other stations between themselves, by creating CFPs per sector. Typically, the sectored traffic within the sectored CFP will have transmission power limitation in order to enable power reduction and in order to minimize the risk of interference from one sector to another. For example, an AP can create a first CFP for a first sector to be used by the traffic from a first station to a second station where both stations are known to be in the region covered by the first

sector. Similarly the AP can simultaneously create a second CFP for the fourth sector, for traffic between the AP and a third station, while ensuring that the traffic in the areas covered by each sector does not interfere with the traffic in the area of the other sector. In the current example the first sector is not used for the traffic itself but only as a geo-topological range. In contrast, the second sector is used for traffic as well. The method proposed to achieve such simultaneous multi-transmissions on the same frequency yet in different sectors is not limited to CSMA protocols, such as the 802.11, but is also applicable and innovative in current WLAN protocols that already use sectors as they were designed for wireless rather than wire-line. The AP can make a decision concerning the simultaneous multi transmissions using location estimation by utilizing the information of the geographical location and/or the network topology of the MTs. Substantially accurate geo-location data, such as gathered from MTs, GPS, or triangulation reports, may be used for topology information. Signal strength, Signal-to-Noise measurements of the received signals of MTs and/or APs by MTs and/or APs in combination with the known transmission level may be used for distance estimation and limited geo-location estimation. Additional methods could be used for such geo-location and distance information where the methods will be typically technology-specific to the wireless technology used. The AP can decide that in one sector two MTs that are close to one another yet are far from the AP can communicate with one another simultaneously as two other MTs in another sector that do not interfere the first pair of MTs (i.e. are not received by them or receive them). The method by utilizing collected information concerning

the sectored infrastructure, increases the capacity of the wireless network. The sectored messages listed in the other preferred embodiment, such as the sectored Beacon and sectored Contention Free Period can be used in CSMA wireless networks to facilitate simultaneous sectored communication. In other wireless networks that already support sectors, the sectored messages can be utilized to facilitate simultaneous communication. In these networks the innovation relates to the planning of the simultaneous communication in accordance with the network topology and the measured distances among the various devices in the network.

Referring now to FIG. 8 showing the manner in which MT1 (226) and MT2 (222) communicate via link 224 with one another. The MT3 (206) and MT4 (204) communicate simultaneously via link 208 with one another. In addition, MT3 (206) with the allowed transmission power level thereof, can also transmit in the uplink 212 to the AP 216 with reasonable success and thereby communicate simultaneously to MT1 (226) and MT2 (222). The AP 216 will facilitate the communication by collecting information concerning the quality of a signal reception by a MT from a transmitting MT. In the protocols already supporting sectors and MTs signal measurements, the present invention provides a function that requests the information in order to provide the feature of simultaneous communication and a function that utilizes collected information (combined with other network information such as traffic requests) to plan and execute simultaneous sectored traffic. In the CSMA networks, which do not support sectored transceiving, such as the 802.11, the present invention provides

the entire mechanisms that facilitate the usage of the sectors. Thus, with the addition of the sectored messages listed on the other embodiments, the AP 216 can create different CFPs per sector so that only the stations that receive that sector are obliged to maintain the CFP. The AP 216 can still use omni-directional CFP such that all the stations are obliged to maintain the CFP. The AP will then switch into sectored transmission, informing the stations at each sector of the period allocated for them (for example by granting the stations transmission permission, or polling the stations), and potentially informing them of various sector related parameters, such as maximum transmission power for the current transmission period.

It will be easily perceived by one with ordinary skill in the art that the steps and components mentioned in the foregoing description were provided as examples and were not intended to be limiting. Diverse other components and methods could be used to accomplish the underlying objectives of the present invention and several enhancements and improvements to the described embodiment could be contemplated within the framework of the general issues inherent in the proposed system.

The above description of the construction and use of systems incorporating a plurality of mobile terminals, access points, network controllers, transceivers, and the like makes particular reference to use in a wireless local area network (WLAN). However, it will be understood that the use of the technique is in no way limited to wireless local area networks (WLAN) and that it is equally

applicable to wireless wide area networks, wireless personal area networks, and other fixed and/or mobile wireless communication systems.

Persons skilled in the art will appreciate that the present invention is not limited to what has been particularly shown and described hereinabove. Rather the scope of the present invention is defined only by the claims, which follow.

I CLAIM:

1. In a wireless communications environment accommodating a set of wireless stations transceiving radio frequency signals, a carrier sense multiple access (CSMA) based wireless communications protocol, a method for implementing sectored transceiving of radio frequency signals, the method comprising the steps of:

   establishing a contention free protected time period to be utilized for sectored transceiving; and

   setting up a directional sector for communication to be utilized for transceiving during the established protected time period.

2. The method of claim 1 wherein the step of establishing comprises broadcasting an omni-directional protected time period creating message.

3. The method of claim 1 wherein the protected time period is a contention free period (CFP).

4. The method of claim 1 wherein the protected time creating message is a sector-relatedly enhanced standard message associated with the CSMA protocol.

5. The method of claim 4 wherein the protected time creating message is a specifically developed and implemented message.

6. The method of claim 1 wherein the step of setting up comprises the sub-steps of:

   transmitting a set of sectored request for communication messages from a source station to a destination station; and

receiving the set of sectored request for communication messages from the source station by the destination station; and

identifying the best-received sectored request out of the set of the sectored request for communication messages by the destination station; and

sending a response message by the destination station indicating the sector through which the identified message was received from the source station;

thereby establishing the optimal sector for transceiving between the source device and the destination device.

7. The method of claim 6 wherein the establishment of the sectors for communication is dynamically determined via network topography related information.

8. The method of claim 7 wherein the network topography is dynamically determined by the information resulting from the step of the setting up of a set of optimal sectors for communication between wireless devices.

9. The method of claim 8 wherein the network topography is dynamically determined by specific geo-location information.

10. The method of claim 8 wherein the specific geo-location information is provided by Global Positioning System (GPS) positioning data.

11. The method of claim 2 wherein the wireless station transmits omni-directionally through an omni-directional antenna.

12. The method of claim 11 wherein the wireless station transmits omni-directionally through the entire set of directional antennas.

13. The method of claim 2 wherein the source station retains the sector-related information linked to the setting up of the optimal sector for communications.

14. The method of claim 1 wherein the protected period is established by the utilization of a sector-relatedly enhanced Ready to Send (RTS) - Clear to Send (CTS) messages.

15. The method of claim 1 wherein the protected period is established through the utilization of a sector-relatedly enhanced Point Coordination Function feature.

16. The method of claim 14 wherein the sector-relatedly enhanced RTS message carries specific sector related information elements.

17. The method of claim 16 wherein the specific information elements include the number of sectors to be tried for transmission, the guard time interval between the messages, and the maximum transmission power allowed on each sector.

18. The method of claim 14 wherein the sector-relatedly improved CTS message carries specific sector related information.

19. The method of claim 18 wherein the specific sector related information regards the sector through which the best received RTS message was received.

20. The method of claim 17 wherein the specific information elements are included in the specifically developed and implemented message type.

21. The method of claim 14 wherein the specifically developed control message is transmitted including information relating to the multiple RTS messages.

22. The method of claim 1 wherein the protected time periods are established per each sector.

23. The method of claim 6 further comprises of sending a sector-relatedly enhanced beacon message including sector-related information transmitted periodically to the entire set of stations in the wireless communication network.

24. The method of claim 23 wherein the sector-relatedly enhanced beacon message is transmitted by a Hybrid Coordination Function, a Hybrid Coordinator, a Control Point function, and a Controlled Contention function.

25. The method of claim 6 further comprises the wireless station listening to the sector-relatedly enhanced beacon message in order to recognize the most suitable sector to transceive through.

26. The method of claim 6 further comprises the dynamic update of the sector information within moving wireless stations.

27. The method of claim 6 further comprises the sending of the update to the Hybrid Coordinator, the Hybrid Coordinator Function, the Control Point Function, and the Controlled Contention function.

28. The method of claim 6 wherein a protected termination message is transmitted by the Hybrid Coordinator, the Hybrid Coordination Function, the Control Point function, and the Controlled Contention function.

29. The method of claim 23 wherein the beacon message is sector-specific.

30. The method of claim 1 wherein the protected time period is created by a sector-relatedly enhanced Transmission Opportunity (TXOP) message.

31. The method of claim 30 wherein the sector-relatedly enhanced TXOP message carries specific sector related information elements.

32. The method of claim 31 wherein the protected time period is created by a regular non-enhanced Transmission Opportunity (TXOP) message.

33. The method of claim 1 wherein the protected time period is established by a sector-relatedly enhanced CF-Poll message.

34. The method of claim 33 wherein the sector-relatedly enhanced CF-Poll message carries specific sector related information elements.

35. The method of claim 1 wherein the protected time period is established by a sector-relatedly enhanced Controlled Contention and related messages.

36. The method of claim 35 wherein the sector-relatedly enhanced Controlled Contention messages carries specific sector related information elements.

37. The method of claim 35 wherein the sector-relatedly enhanced Controlled Contention message is operative in declaring a specific priority value assigned to a set of stations operative in enabling the set of stations to contend for the wireless media.

38. The method of claim 1 wherein the protected time period is created by the transmission of diverse CSMA protocol-specific messages.

39. In a wireless communications environment accommodating a set of wireless stations having a set of directional antennas associated with sectors having the same directionality transceiving radio frequency signals through the set of the directional antennas, a carrier sense multiple access based wireless communications protocol, a system for implementing sectored transceiving of radio frequency signals, the system comprising the elements of:

a set of sectored wireless stations; and

a sectored access point device; and

a sectored control point device; and

a sectored traffic management component; and

a sectored messaging component.

40. The system of claim 39 wherein the sectored traffic management module further comprises the elements of:

a time scheduler module; and

a frequency scheduler module; and

a geographical domain handler; and

a power control module.

41. The system of claim 39 wherein the set of sectored wireless stations further comprises the elements of:

a set of antennas devices having varied directionality; and

an omni-directional antenna device.

42. The system of claim 39 wherein the set of antennas having varied directionality are directly associated with directional communication sectors.

43. The system of claim 39 wherein the a carrier sense multiple access and collision handling device includes the elements of:

an sectored hybrid coordination function; and

a sectored point coordination function; and.

a sectored network allocation vector.

44. The system of claim 39 wherein the carrier sense multiple access based wireless communications protocol is the 802.11 protocol with associated, ratified and proposed enhancements.

45. In a wireless communications environment accommodating a set of wireless stations transceiving radio frequency signals, a carrier sense multiple access (CSMA) based wireless communications protocol, a method for implementing sectored transceiving of radio frequency signals, the method comprising the steps of:

establishing a set of sector-specific contention free protected time periods to be utilized for sectored transceiving; and

setting up a set of directional sectors associated with the sector-specific protected time periods for communication to be utilized for sectored transceiving during the established sector-specific protected time periods; and

collecting network stations-related sectored data, geo-location data, and distance data; and

scheduling of simultaneous sectored transceiving based on the collection of the network stations-related sectored data, geo-location data, and distance data.

46. The method of claim 45 further comprising inserting measurement data for at least one sector into the messages, transmitted by a source station.

47. The method of claim 45 further comprising including measurement data concerning a subset of sectors into the messages, transmitted by a source station.

48. The method of claim 45 wherein in a multicast traffic mode the enhanced protected period creating messages are received by a set of network stations listening on a specific sector.

49. The method of claim 45 wherein the set of network stations return messages and measurement and location report to the source station.

50. The method of claim 45 further comprises transmission scheduling between the network stations based on the accumulated sector-related information.

51. The method of claim 50 wherein the accumulated sector-related information includes data concerning a subset of sector to poll and a subset of network stations to poll.

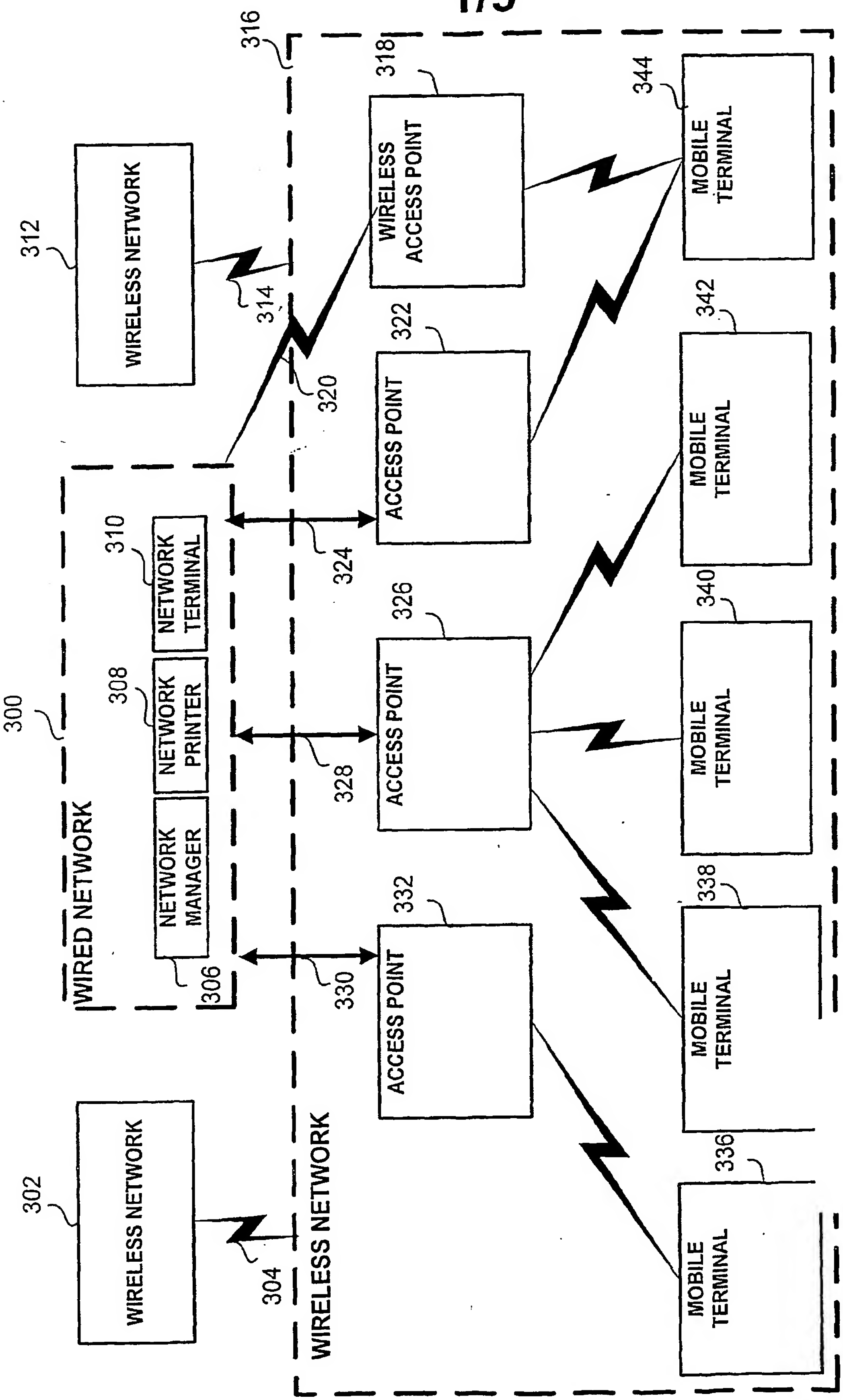


FIG. 1A
PRIOR ART

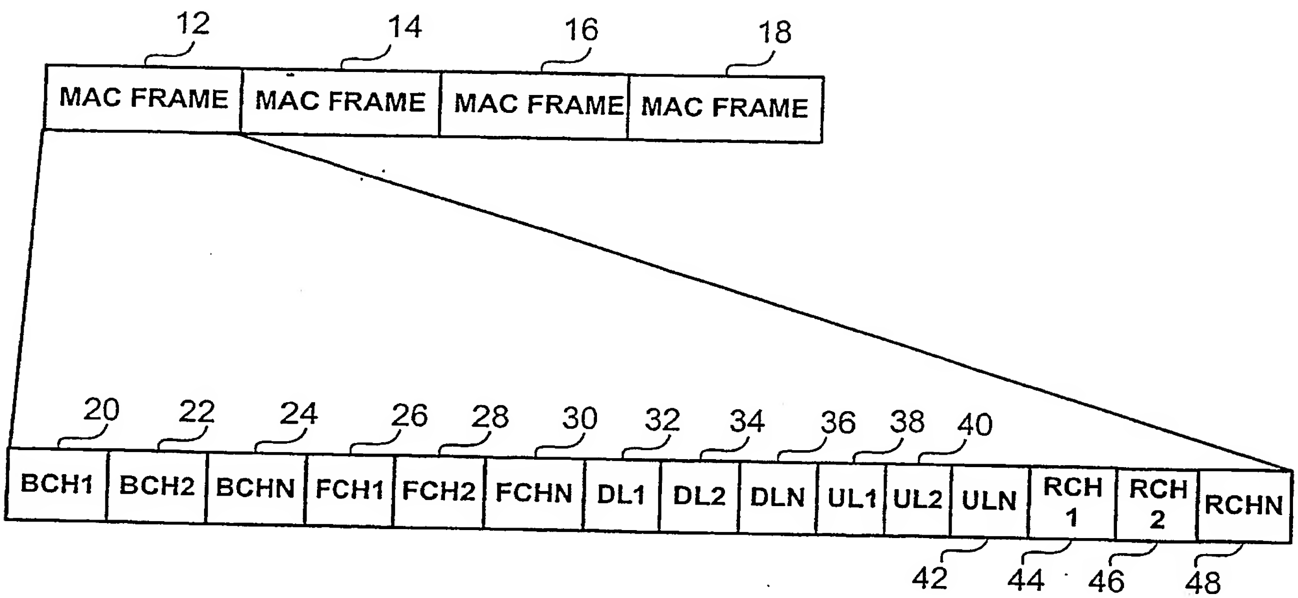


FIG. 1B
PRIOR ART
(SECTORED HIPERLAN/2 - TDMA FRAME)

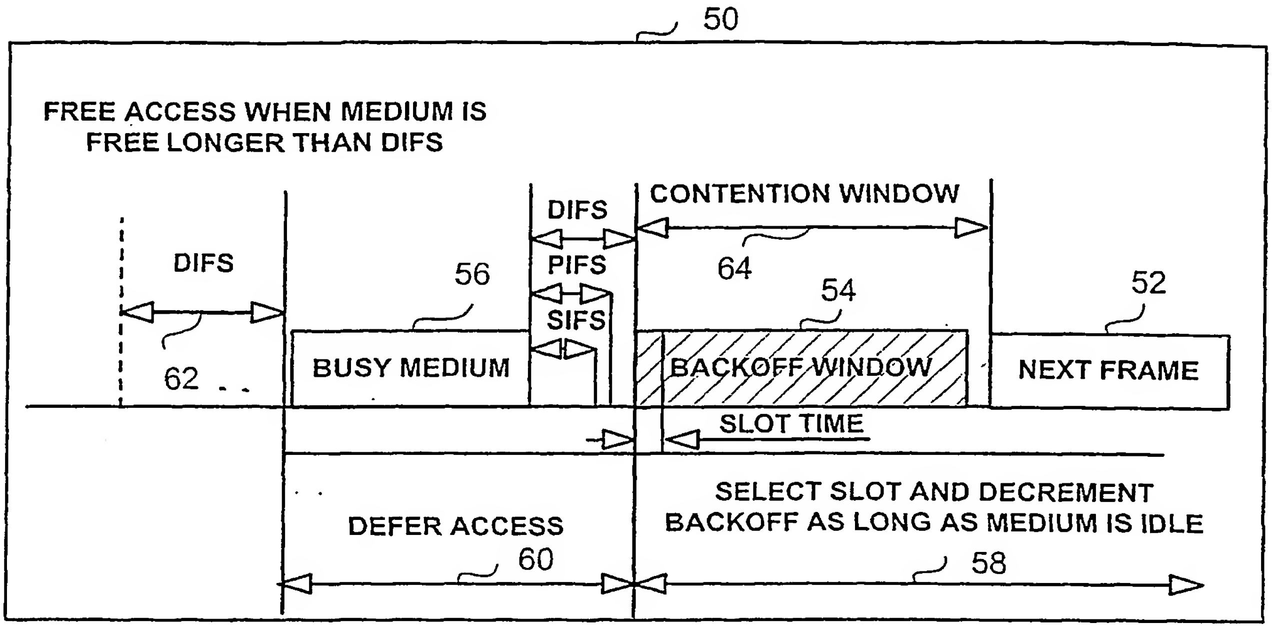


FIG. 2A
PRIOR ART - CSMA/CA

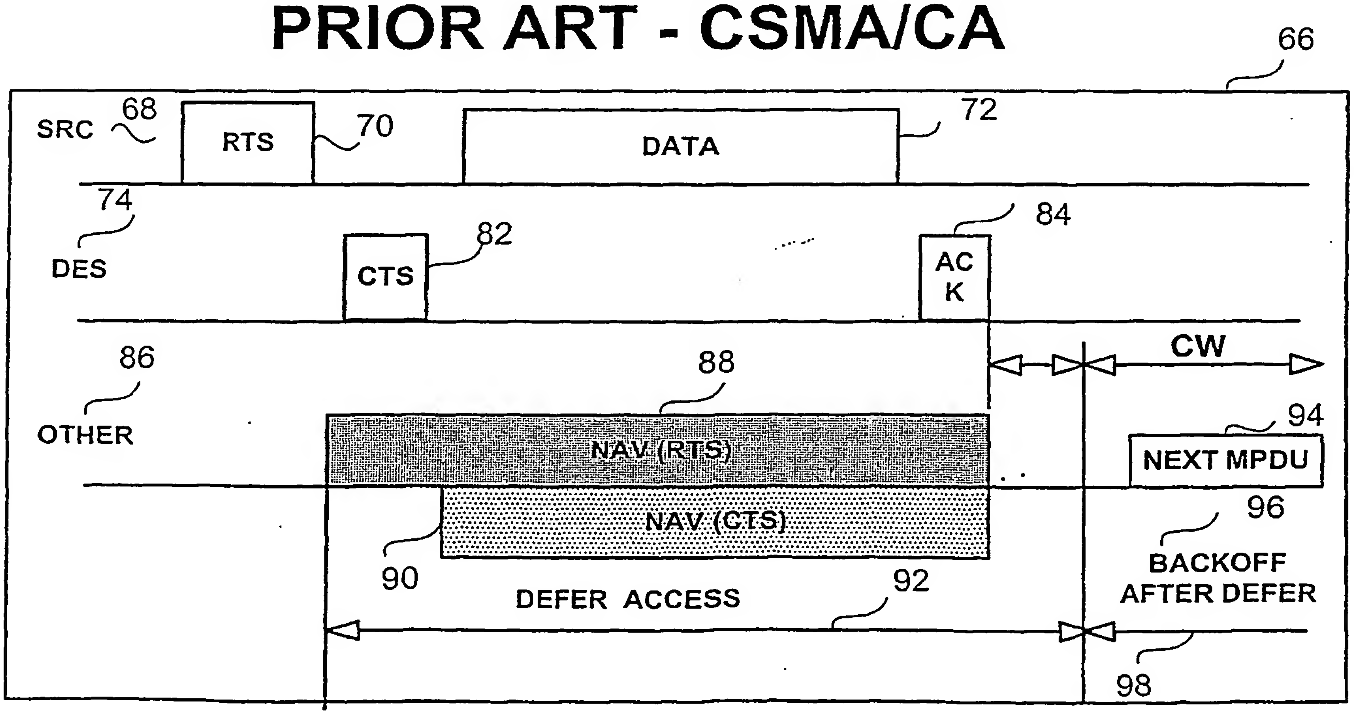


FIG. 2B
PRIOR ART - 802.11

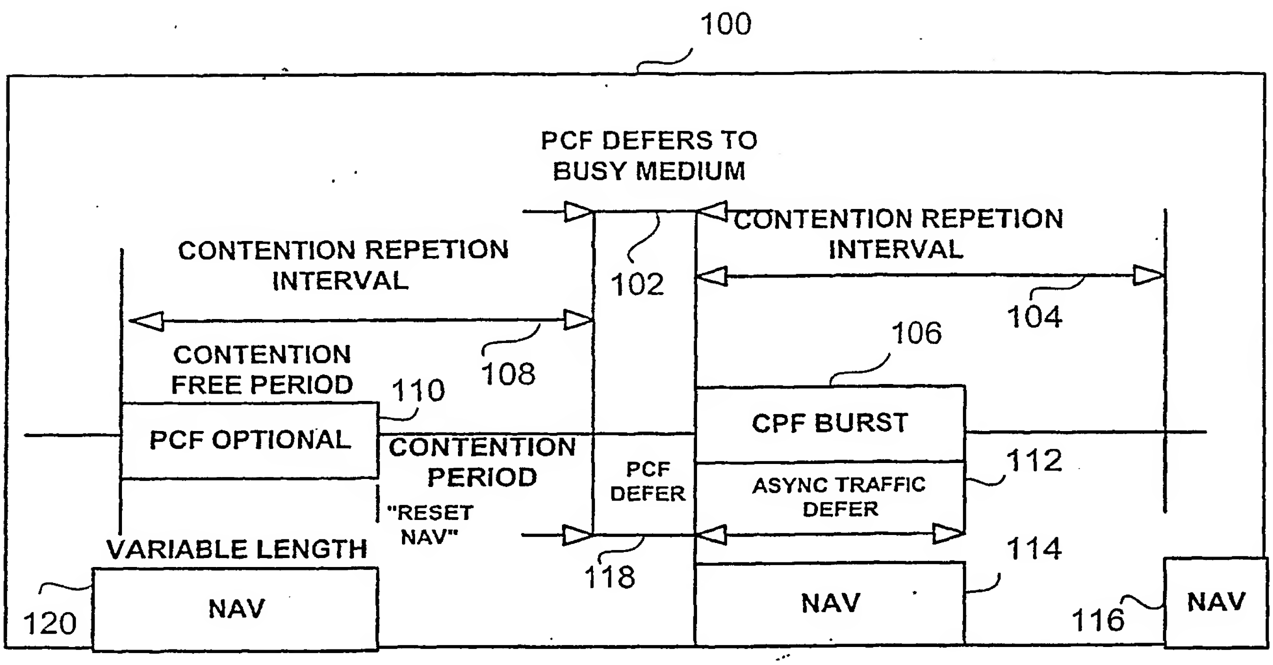


FIG. 3
PRIOR ART - CREATING CFP

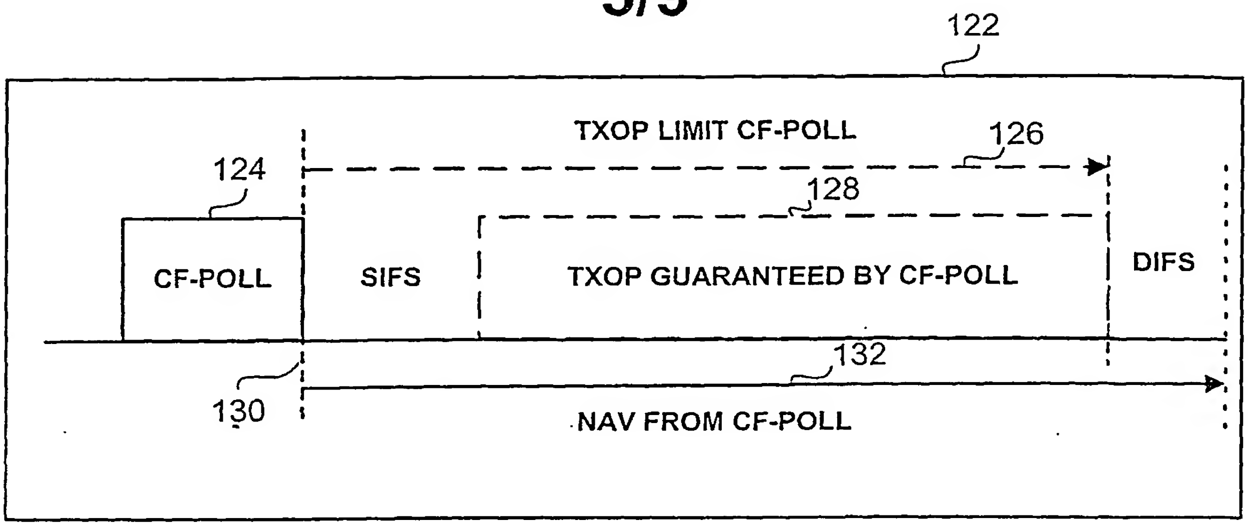


FIG. 4A
PRIOR ART

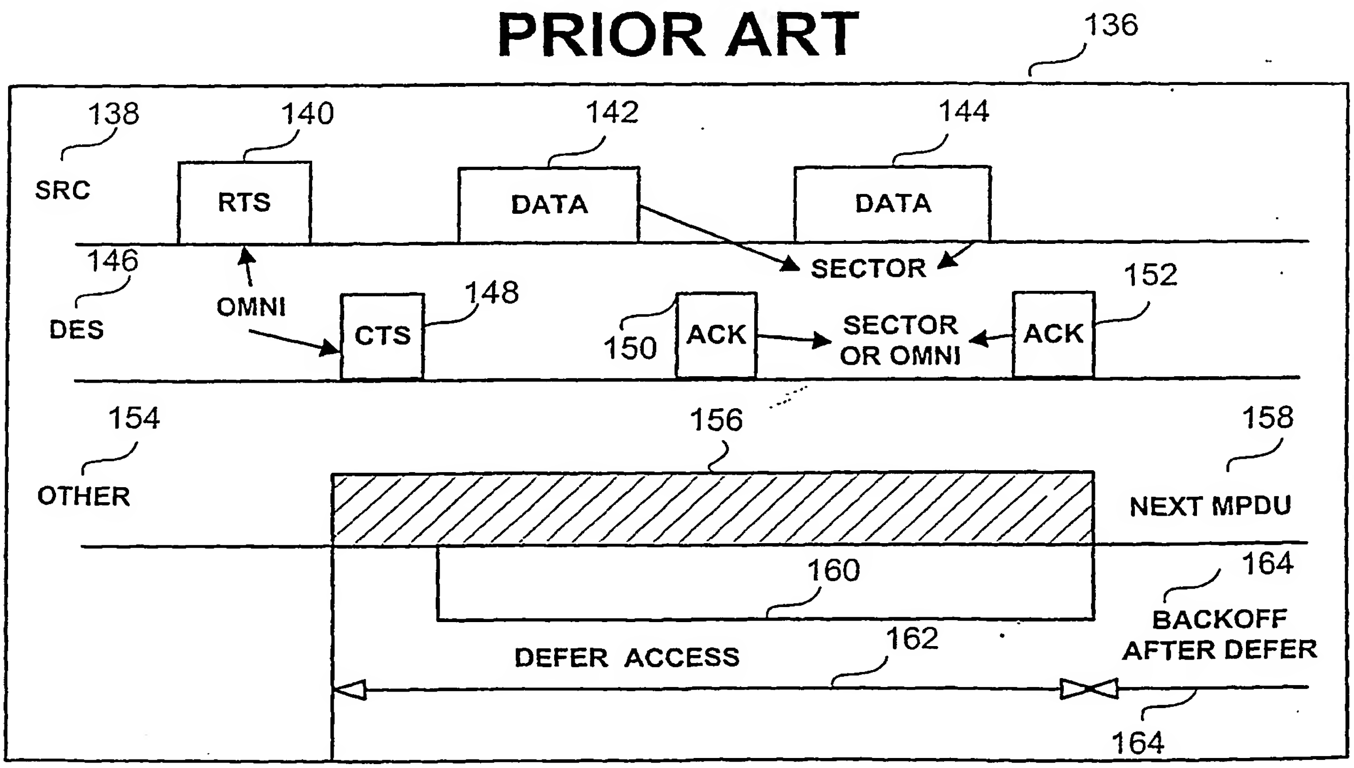
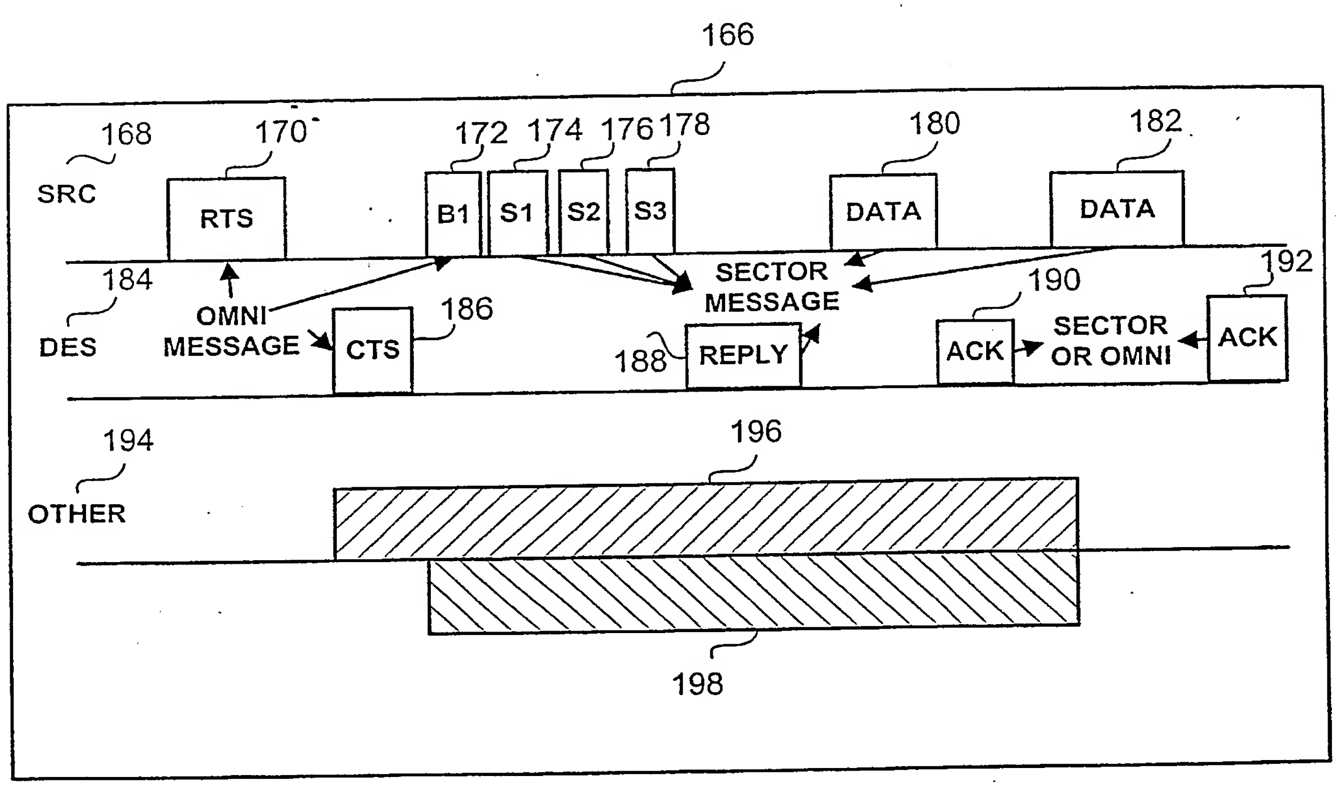


FIG. 4B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SRC
170
RTS
172
B1
174
S1
176
S2
178
S3
180
DATA
182
DATA
184
DES
OMNI
MESSAGE
CTS
186
SECTOR
MESSAGE
188
REPLY
190
ACK
SECTOR
OR OMNI
192
ACK
194
OTHER
196
198

FIG. 5

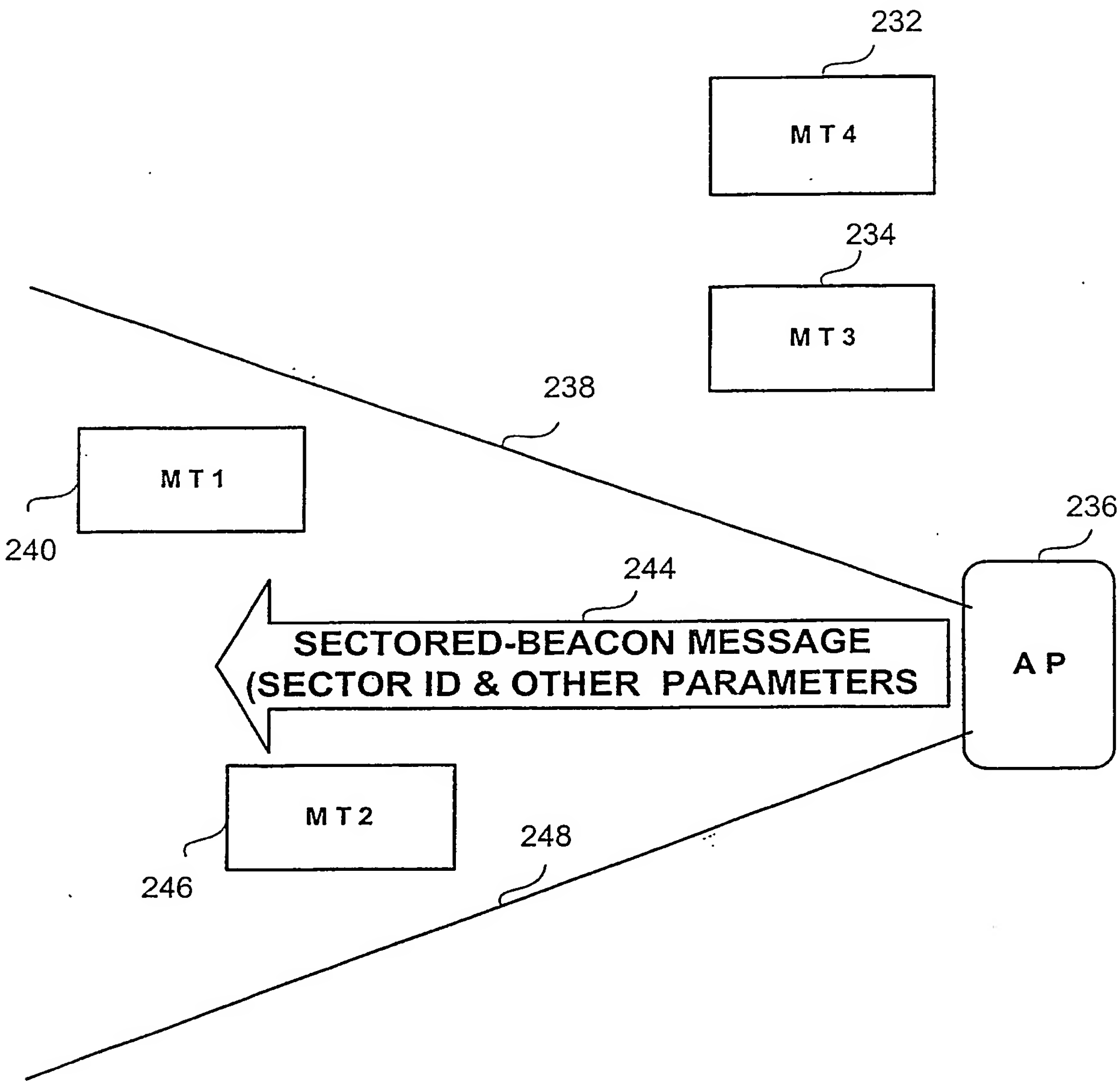

232
M T 4
234
M T 3
238
M T 1
240
236
244
SECTORED-BEACON MESSAGE
(SECTOR ID & OTHER PARAMETERS
A P
M T 2
248
246

FIG. 6

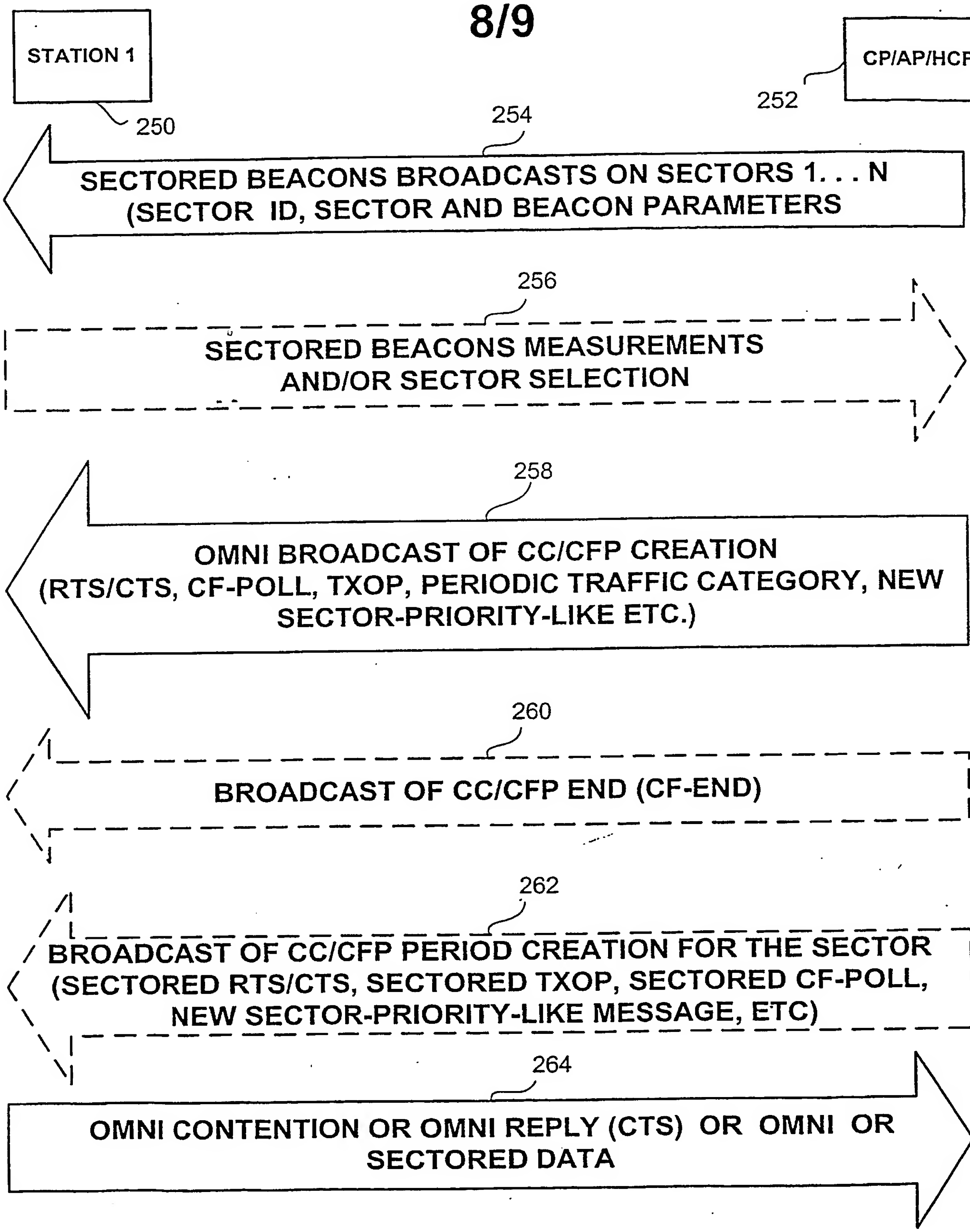
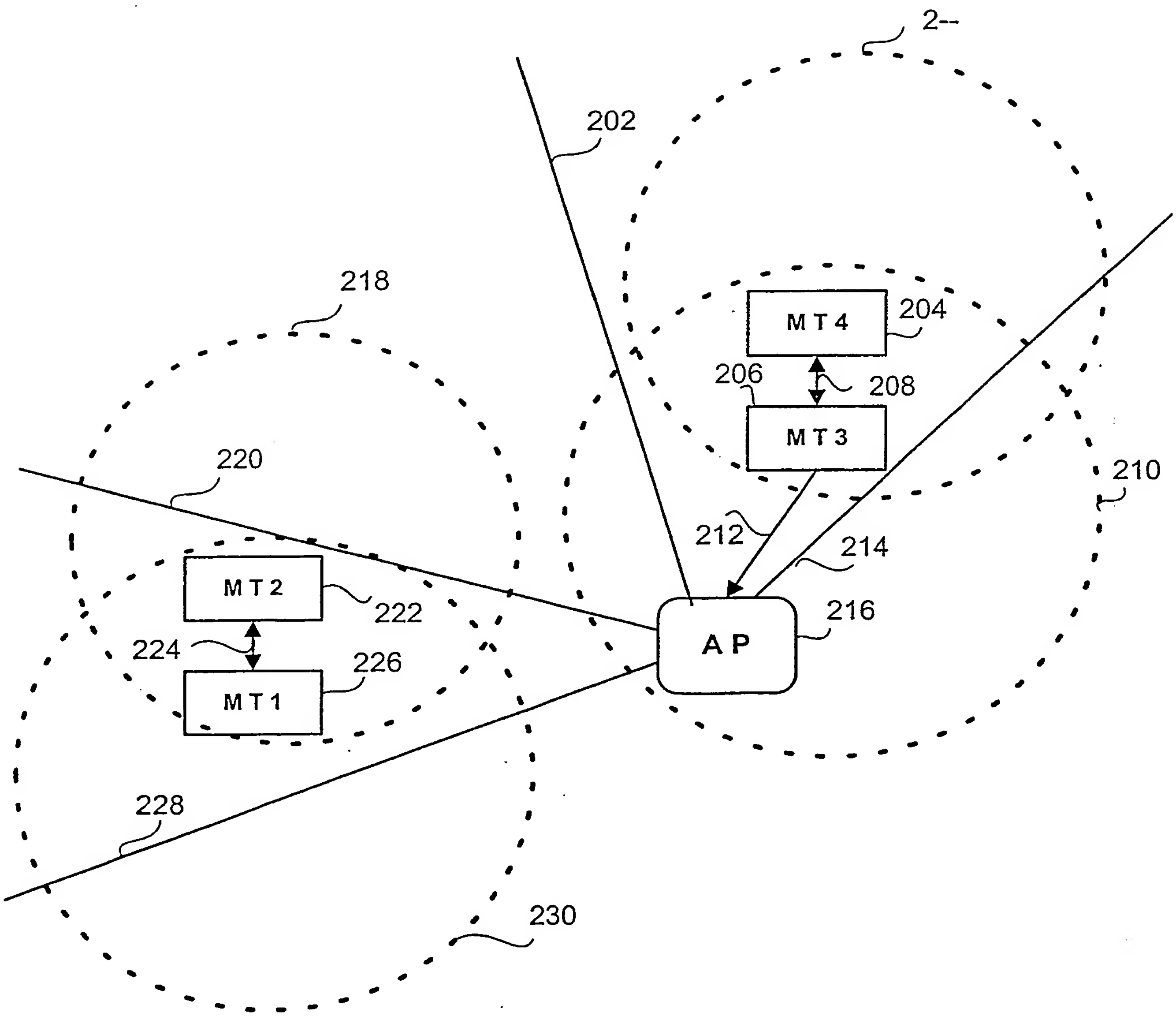

STATION 1
250
CP/AP/HCF
252
254
SECTORED BEACONS BROADCASTS ON SECTORS 1. . . N
(SECTOR ID, SECTOR AND BEACON PARAMETERS
256
SECTORED BEACONS MEASUREMENTS
AND/OR SECTOR SELECTION
258
OMNI BROADCAST OF CC/CFP CREATION
(RTS/CTS, CF-POLL, TXOP, PERIODIC TRAFFIC CATEGORY, NEW
SECTOR-PRIORITY-LIKE ETC.)
260
BROADCAST OF CC/CFP END (CF-END)
262
BROADCAST OF CC/CFP PERIOD CREATION FOR THE SECTOR
(SECTORED RTS/CTS, SECTORED TXOP, SECTORED CF-POLL,
NEW SECTOR-PRIORITY-LIKE MESSAGE, ETC)
264
OMNI CONTENTION OR OMNI REPLY (CTS) OR OMNI OR
SECTORED DATA

FIG. 7


2--
202
218
MT4
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206
208
MT3
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MT2
222
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AP
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226
MT1
228
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FIG. 8

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IL 01/00880

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L12/413 H04L12/28 H04L12/56

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04L H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 634 853 A (VICTOR COMPANY OF JAPAN LTD.) 18 January 1995 (1995-01-18) abstract; figures 1-8 column 3, line 15 - line 33 column 11, line 14 -column 12, line 42 ---	1,45
A	US 5 274 841 A (NATARAJAN ET AL.) 28 December 1993 (1993-12-28) abstract; figures 1-7 column 6, line 58 -column 7, line 21 column 11, line 11 - line 62 ---	1,45
A	WO 99 14897 A (TELEFONAKTIEBOLAGET LM ERICSSON) 25 March 1999 (1999-03-25) abstract; figures 7,9,11 page 23, line 6 -page 24, line 28 page 25, line 19 -page 26, line 11 --- -/--	1,7,8

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 May 2002	05/06/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Danielidis, S

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

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